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THE USE OF COVER CROPS TO CONTROL TREE INVASION ON A RIGHT-OF-WAY NEAR TOBERMORY I. PRECLEARING CONDITIONS AND A RESEARCH PROPOSAL

Report No 88-296-K

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ABSTRACT

Investigations were carried out on distribution rights-of-way on the Bruce Peninsula near Tobermory to determine a location suitable for an experimental comparison of the ability of grasses, legumes and the natural right-of-way vegetation cover to interfere with tree invasion. A location has been selected for the experiment, and the following is a report on the preclearing vegetation and soil conditions at that site. A research proposal is also included which outlines the experimental design and discusses additional factors which are desirable in such a study.

job 34-539-031	file 834.1	date February 7, 1989	report 88-296-K

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EXECUTIVE SUMMARY

THE USE OF COVER CROPS TO CONTROL TREE INVASION ON A RIGHT-OF-WAY NEAR TOBERMORY I. PRECLEARING CONDITIONS AND A RESEARCH PROPOSAL

D. Brown
Biological Research Section
Chemical Research Department

In the past two decades Ontario Hydro has relied on selective herbicide applications to remove incompatible species from their transmission and distribution rights-of-way. This approach was designed to encourage a type of biological control, where the compatible groundcover interferes with the invasion of tree species via competitive or allelopathic interactions. The success of this technique is dependent upon the presence of species in the area which are able to successfully interfere with tree establishment and/or growth. If such species are not present, or are unable to establish on the right-of-way, no effective biological control can develop.

An alternative method of establishing this control is by replacing the existing vegetation with species that have a demonstrated ability to interfere with tree establishment. Cover crops have been used by Ontario Hydro for erosion control and aesthetic purposes for a number of years, but few studies have been undertaken to determine their possible role in a biological control strategy.

All distribution lines in the Tobermory area of the Bruce Peninsula scheduled for clearing during the fall and winter of 1988 were included in a preliminary survey to select potential research sites. Primary factors considered in the selection of a site were: width of the right-of-way, forest composition, uniformity of the vegetation, soil depth, and the amount of gravel, boulders and exposed bedrock at each location.

From this survey, 10 sites on a 3.5 km section of right-of-way running from Eagle Harbour to Pendal Point have been selected for an experimental evaluation of cover crops. The soil in this area is a thin, sand to sandy loam, covered with a 10-15 cm humus layer. The sites have similar vegetational compositions. Incompatible species in the area consist of balsam fir (*Abies balsamea*) and white cedar (*Thuja occidentalis*), while the ground vegetation is dominated by twinflower (*Linnaea borealis*), starflower (*Trientalis borealis*) and flowering wintergreen (*Polygala paucifolia*).

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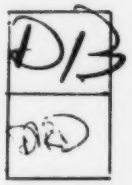
The proposed cover crop experiment will consist of a random block design, with 5 treatment plots per block. All plots will be cleared of incompatible vegetation prior to the experiment. The treatments will consist of: 1) scarifying and seeding with red fescue (*Festuca rubra*), 2) scarifying, seeding with red fescue and a fertilizer application, 3) scarifying and seeding with crown vetch (*Coronilla varia*), 4) scarified control (not seeded) and 5) a non-scarified and non-seeded control.

Evaluation of the experiment will be conducted at the end of the first growing season, at yearly intervals for an additional 3 to 4 years, and subsequently at 2 to 4 year intervals. This will involve measuring the extent of tree invasion into each plot, and determining the actual composition of the vegetation of each plot.

This experimental design will allow for a comparison of the relative effectiveness of the cover crops and the current vegetation management practices. Sampling during the the establishment, maturation and senescent phases of the cover crop will also indicate which of these stages are more susceptible to invasion, providing an indication of the useful longevity of the crops.



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To: Dr. D. Mills
Director of Research

THE USE OF COVER CROPS TO CONTROL TREE INVASION ON A RIGHT-OF-WAY NEAR TOBERMORY I. PRECLEARING CONDITIONS AND A RESEARCH PROPOSAL

1.0 INTRODUCTION

Electrical Power Utilities have relied on herbicides since the 1940's as the mainstay of their vegetation control programs. This is likely to change. The past decade has seen increased public concern over herbicides and other environmental issues, culminating in the recent announcement by the executive office of Ontario Hydro that herbicide usage will be reduced. This emphasizes the need to investigate alternatives for the control of unwanted vegetation on Ontario Hydro's rights-of-way. The mechanical alternatives of hand cutting or mowing do not provide good long term control over unwanted trees (Johnston 1985). Biological control alternatives, where interference mechanisms (competition and allelopathy) of vegetation assist in the reduction of incompatible species are environmentally more sound, but require further investigation.

Biological control can play an important role in rights-of-way maintenance (Egler 1958). However, the best method of establishing this control has not been well investigated. Selective herbicide sprays, which remove the unwanted (incompatible) vegetation with minimal effects on the remaining ground cover, have led to the establishment of pseudo-stable plant communities in some locations (Niering and Goodwin 1974, Bramble and Byrnes 1976). Unfortunately these highly desirable communities occupy only a small fraction of our rights-of-ways, and their creation is a poorly understood and highly fortuitous event (Jotcham 1985). An alternative approach is to remove the existing right-of-way vegetation, and plant species which have been shown to have better interference mechanisms. Cover crops have been used previously by Ontario Hydro, but primarily for erosion control and aesthetic purposes. A review of Ontario Hydro's previous cover crop studies indicates that the brush control achieved by the cover crop is generally more effective than either blanket herbicide usage or selective cutting (Suffling 1979). Unfortunately, the test plots set up were highly inadequate (Suffling 1979) and little experimentation has been undertaken in this area in recent times.

Competition occurs in situations where different individuals require the same resource, such as nutrients, moisture, light and space. The removal of some of the resource by one individual interferes with the growth of another. When the available amount or supply of that resource is below that required by the community, competition will often result in a change in community structure by the displacement of poor competitors by better competitors. This has been implicated as one of the major factors in vegetational succession (Tilman 1985). Allelopathic

interactions occur when an individual excretes a chemical to the environment which inhibits the growth or germination of other individuals. This interaction has been recently implicated as a potential cause of forest regeneration failure (Horsley 1977a, Fisher 1980). The relative contribution of competition and allelopathy is difficult to determine, especially in field experiments, therefore the more general term of interference will be used.

A study is currently investigating the interference effects of existing right-of-way communities (Brown 1988). The Georgian Bay Region approached the Biological Research Section to investigate distribution lines on the Bruce Peninsula for a potential site for a cover crop trial. A possible location has been identified for this trial, and this report describes the site and discusses an experimental design for the cover crop experiment.

2.0 METHODS

All distribution lines in the Tobermory area of the Bruce Peninsula scheduled for clearing during the fall and winter of 1988 were included in a preliminary survey to select potential research sites. Primary factors considered in the selection of a site were: width of the right-of-way, forest composition, uniformity of the vegetation, soil depth, and the amount of gravel, boulders and exposed bedrock at each location. From this survey, two potential sites were selected; a 3.5 km section running from Eagle Harbour to Pendal Point (pole 49258-25 to 11435-50) and a 5 span segment of line near Hopkins Bay (3215-50 to 3381-5) (Figure 1). Both sites were heavily overgrown with incompatible vegetation and clearing would leave a 10 m wide right-of-way. The Hopkins Bay line is treed on both sides while the other site has a road on the east boundary of the right-of-way. The Hopkins Bay line was frequently crossed by cottage laneways. This is undesirable as it fragmented the study area into blocks which are too small to permit more than one experimental plot in each block. In contrast, the Eagle Harbour - Pendal Point right-of-way has 10 stretches 3 to 4 spans (225-300 m) in length uninterrupted by cottage areas (Figure 2). A uninterrupted area of this size is more suitable for the inclusion of several experimental plots per area. Therefore the Hopkins Bay location was rejected in favour of the Eagle Harbour - Pendal Point line.

A survey of the vegetation at these 10 sites was conducted in August and September of 1988. One pole at each site was randomly selected. Two macroquadrats of 5 x 10 m were located 10 m on either side of this pole, centered in the middle of the line, with the long axes of the quadrat running parallel to the right-of-way. Ten 0.5 x 0.5 m microquadrats were randomly located within each macroquadrat. The number of tall shrubs and trees (above 0.5 m in height) in each macroquadrat was enumerated, while the cover of all vegetation was subjectively assessed in the microquadrats using the Domin scale (Table I). Nomenclature follows Fernald (1950), Soper and Heimburger (1982) and Hosie (1979) for the herbs, shrubs and trees respectively. A complete species list is included as Table II.

One randomly placed soil sample was taken at each site, and analyzed by the Department of Land Resource Science, University of Guelph, for magnesium, potassium, calcium, % organic matter and pH. Soil texture and an estimate of the thickness of the humus and mineral soil layers was determined at the time of the vegetation survey and included in the site descriptions (Table III).

The microquadrat data was ordinated using the reciprocal averaging option of DECORANA (Hill and Gauch 1980) with downweighting of rare species. One outlier sample (site 1, macroquadrat B, microquadrat 6) was excluded from the ordination analysis.

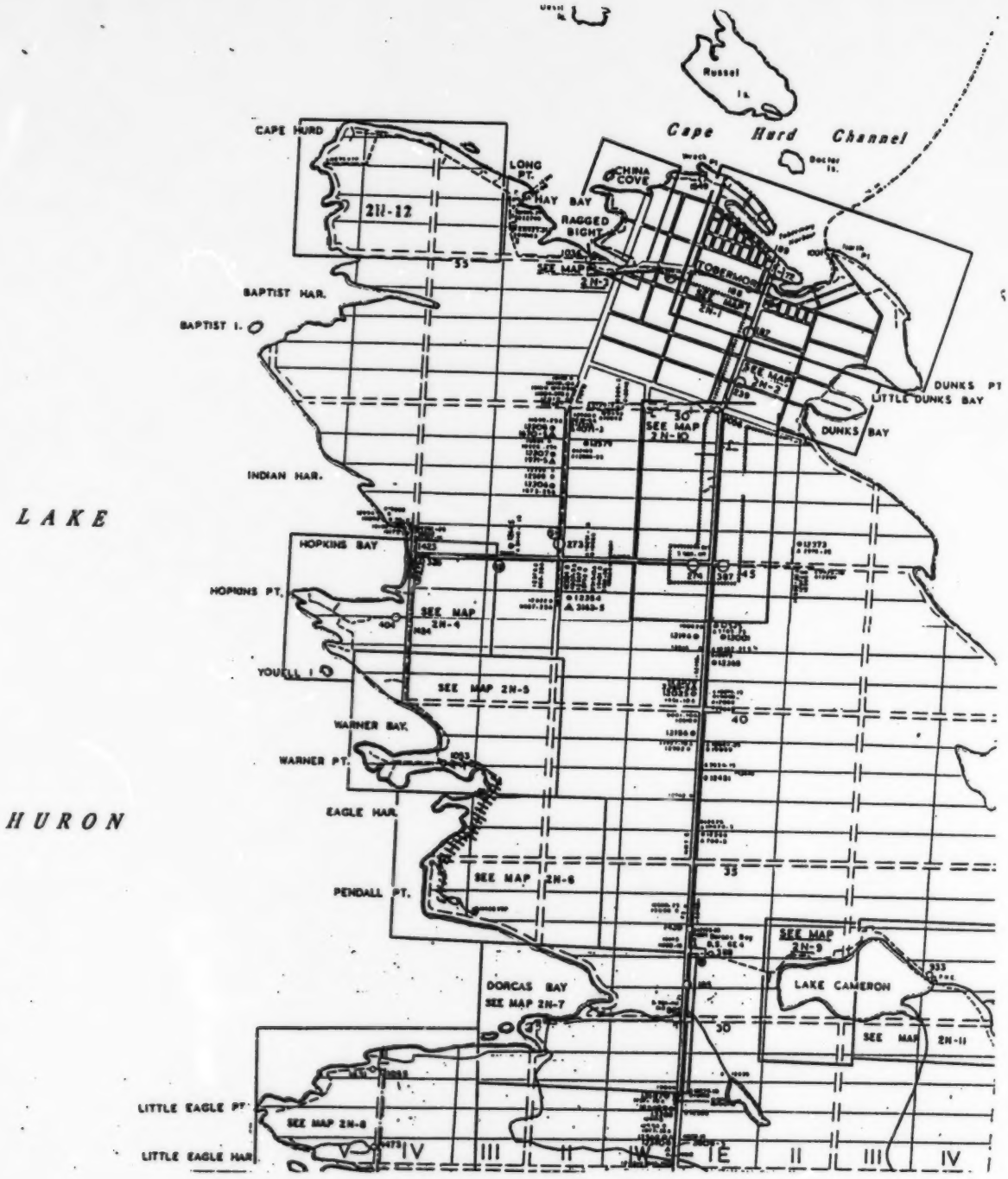

FIGURE 1

A MAP OF THE BRUCE PENINSULA NEAR TOBERMORY.
CROSS HATCHING INDICATES THE LOCATION OF THE HOPKINS BAY
AND EAGLE HARBOUR TO PENDAL POINT DISTRIBUTION
RIGHTS-OF-WAY

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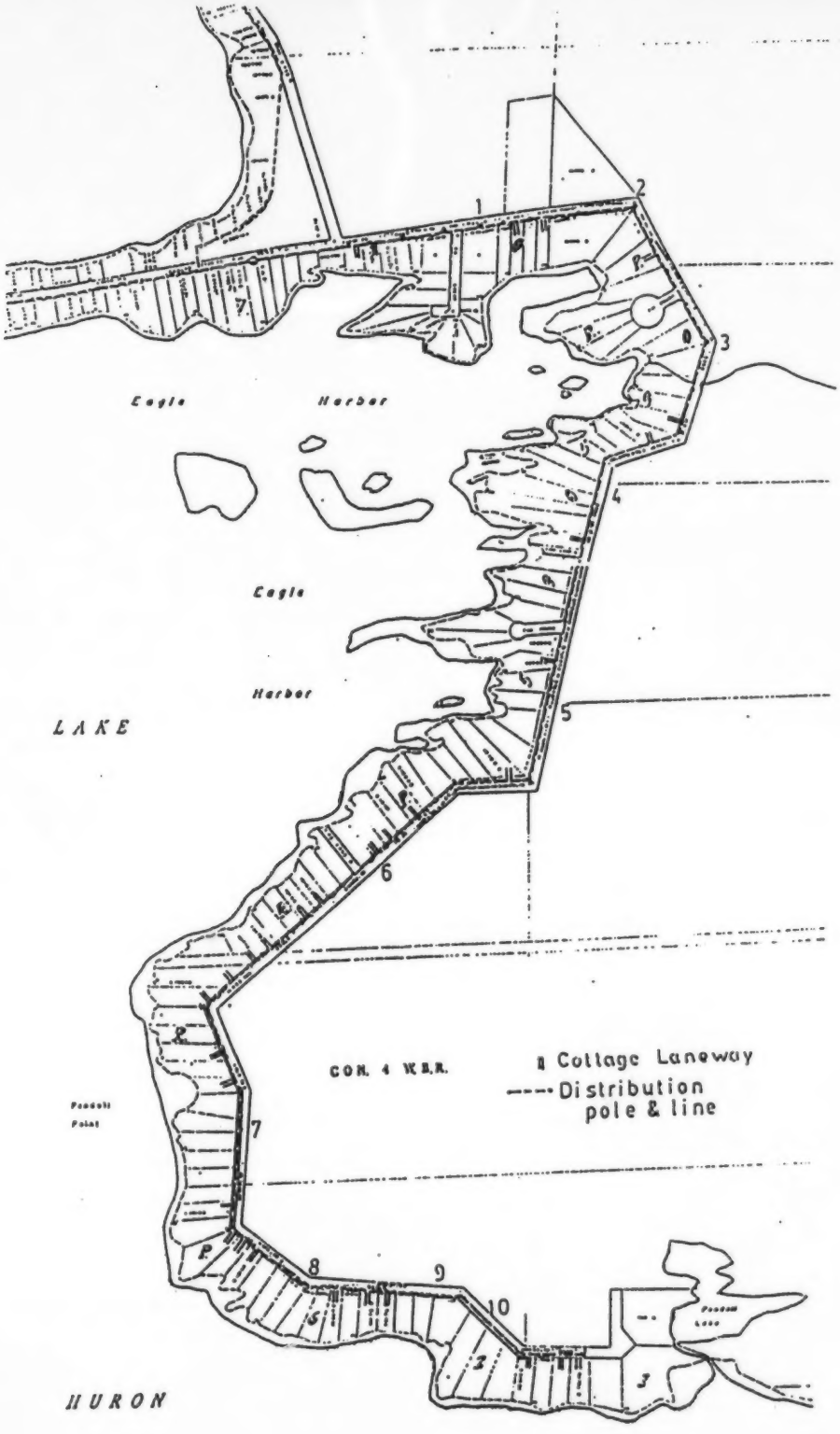

FIGURE 2

A MAP OF THE EAGLE HARBOUR TO PENDAL POINT DISTRIBUTION LINE, INDICATING THE LOCATION OF THE 10 SAMPLING SITES

Table I

The Domin scale of plant abundance and cover

Abundance	Rating
Cover about 100%	10
Cover above 75%	9
Cover of 50 to 75%	8
Cover of 33 to 50%	7
Cover of 25 to 33%	6
Abundant, cover of 20 to 25%	5
Abundant, cover of 5 to 20%	4
Scattered with small cover	3
Very scattered with small cover	2
Scarce, small cover	1

Table II

A complete list of species found in the study, and
their number of occurrences in the 200 0.5 x 0.5 m microquadrats

Species	Common name	Abbreviation	Occurrences
Abies balsamea	balsam fir	Abie bal	86
Achillea millefolium	yarrow	Achi mil	7
Aesculus pedantum	horse chestnut	Aesc ped	0
Agrostis alba	red top bentgrass	Agro alb	10
Anaphalis margaritacea	pearly everlasting	Anap mar	2
Anemone canadensis	Canada anemone	Anem can	2
Aquilegia canadensis	columbine	Aqui can	5
Aralia nudicaulis	Sarsaparilla	Aral nud	13
Arctostaphylos uva-ursi	bearberry	Arct uva	16
Aster lowrieanus	Lowries aster	Aste low	14
Aster macrophyllus	large leaved aster	Aste mac	55
Aster novae-angliae	New England aster	Aste nov	2
Aster puniceus	purple stemmed aster	Aste pun	6
Aster umbellatus	flat topped aster	Aste umb	2
Betula papyrifera	white birch	Betu pap	10
Bulbostylis capillaris	hair rush	Bulb cap	18
Carex rupestris	rock sedge	Care rup	3
Carex sylvatica	wood sedge	Care syl	7
Cerastium vulgatum	mouse eared chickweed	Cera vul	1
Chrysanthemum leucanthemum	common daisy	Chry leu	23
Clintonia borealis	blue bead lily	Clin bor	3
Cornus canadensis	bunchberry	Corn can	42

Table II (cont'd)

A complete list of species found in the study, and
their number of occurrences in the 200 0.5 x 0.5 m microquadrats

Species	Common name	Abbreviation	Occurrences
Cornus florida	flowering dogwood	Corn flo	1
Cornus rugosa	round leaved dogwood	Corn rug	2
Cornus sp.	dogwood	Corn sp.	2
Cornus stolonifera	red osier dogwood	Corn sto	1
Corylus cornuta	beaked hazelnut	Cory cor	1
Daucus carota	wild carrot	Dauc lon	8
Diervilla lonicera	bush honeysuckle	Dier loi	5
Elymus repens	couch grass	Elym rep	6
Epilobium angustifolium	fireweed	Epil ang	1
Equisetum arvense	field horsetail	Eque arv	16
Equisetum pratense	shade horsetail	Eque pra	2
Equisetum scirpoides	dwarf scouring rush	Eque sci	1
Fragaria virginiana	strawberry	Frag vir	47
Fraxinus pensylvanica	green ash	Frax pen	0
Galium triflorum	fragrant bedstraw	Gali tri	5
Gaultheria hispidula	creeping snowberry	Gaul his	9
Geum virginianum	rough avens	Geum vir	2
Goodyera tesselata	checkered rattlesnake plantain	Good tes	3
Halenia deflexa	spurred gentian	Hale def	4
Hieracium aurantiacum	orange hawkweed	Hier aur	10
Hypericum perforatum	common St. John's wort	Hype per	13
Juniperus communis	ground juniper	Juni com	0
Juniperus horizontalis	creeping juniper	Juni hor	5
Lactuca hirsuta	hairy lettuce	Lact hir	3
Linnaea borealis	twinflower	Linn bor	116
Lonicera canadensis	fly honeysuckle	Loni can	6
Lonicera involucrata	northern honeysuckle	Loni inv	5
Lonicera oblongifolia	swamp fly honeysuckle	Loni obl	1
Maianthemum canadense	wild lily of the valley	Maia can	62
Melampyrum lineare	cow wheat	Mela lin	9
Melilotus alba	white sweet clover	Meli alb	5
Mitella nuda	naked miterwort	Mite nud	8
Myrica gale	sweet gale	Myri gal	1
Parnassia glauca	Grass of Parnassus	Parn gla	3
Phleum pratense	timothy	Phle pra	1
Picea glauca	white spruce	Pice gla	3
Picea mariana	black spruce	Pice mar	5
Plantago lanceolata	English plantain	Plan lan	2
Poa compressa	Canada bluegrass	Poa com	5
Polygala paucifolia	flowering wintergreen	Poly pau	84
Populus balsamifera	balsam poplar	Popu bal	0

Table II (cont'd)

A complete list of species found in the study, and
their number of occurrences in the 200 0.5 x 0.5 m microquadrats

Species	Common name	Abbreviation	Occurrences
Populus tremuloides	trembling aspen	Popu tre	0
Potentilla anserina	silverweed	Pote ans	1
Potentilla fruticosa	shrubby cinquefoil	Pote fru	2
Prunella vulgaris	heal all	Prun vul	7
Prunus serotina	black cherry	Prun ser	0
Prunus virginiana	chokecherry	Prun vir	3
Pteridium aquilinum	bracken fern	Ptri aqu	18
Rhus radicans	poison ivy	Rhus rad	11
Ribes sp.	gooseberry	Ribe sp.	4
Rosa acicularis	prickly wild rose	Rosa aci	12
Rubus idaeus	common raspberry	Rubu ida	26
Rubus pubescens	dwarf raspberry	Rubu pub	11
Salix sp.	willow	Sali sp.	2
Satureja vulgaris	basil	Satu vul	20
Shepherdia canadensis	soapberry	Shep can	2
Silene cucubalus	bladder campion	Sile cuc	2
Solidago altissima	tall goldenrod	Soli alt	2
Solidago canadensis	Canada goldenrod	Soli can	10
Solidago hispida	hairy goldenrod	Soli his	7
Solidago juncea	early goldenrod	Soli jun	6
Sorbus americana	mountain ash	Sorb ame	1
Taraxacum dioicum	dandelion	Tara dio	1
Thuja occidentalis	white cedar	Thuj occ	54
Trientalis borealis	starflower	Trie bor	87
Trifolium hybridum	alsike clover	Trif hyb	1
Tussilago farfara	coltsfoot	Tuss far	3
Vaccinium angustifolium	blueberry	Vacc ang	1
Viola spp.	Viola spp	Violet	10
unidentified species			14

Table III

Field descriptions of the proposed study sites

Site 2

Wide right-of-way open to roadside.
Sloped away from road down to brush containing white cedar, balsam fir and white spruce.
Soil is gravel and fine sand (possibly a fill) over bedrock.

Site 3

Right of way is bordered by white cedar and balsam fir
Thick humus layer (10-15 cm) over a shallow sandy soil and bedrock.

Site 4

Partially open road and hydro right-of-way surrounded by balsam fir, white birch, white spruce and white cedar.
10-15 cm humus layer over bedrock.
Ground is flat with a north-south aspect.
Site 4A has a very thick mat of creeping juniper on the right-of-way, while 4B has heavy advance regeneration of white cedar, balsam fir and white birch.

Site 5

Enclosed right-of-way, with a north-south aspect bounded by cedar, white birch and black spruce.
5A has a thin humus layer (5 cm) underlain by 12-15 cm of sandy soil over bedrock, while 5B has a much shallower soil with much exposed bedrock.

Site 6

Flat surface heavily bordered by white cedar and balsam fir.
5 cm humus layer over shallow loamy soil and bedrock.

Site 7

Relatively open site with a north-south aspect, bounded by white cedar and white birch on the west and a broken line of cedar on the east.
5 cm humus layer overlying a thin loam soil and bedrock.

Site 8

Scattered white cedar on the east, with white cedar and white birch on the west.
Ground is uneven, with gentle undulations.
Thick humus layer (20 cm) over a thin sandy loam.

Site 9

North-south aspect, open on the east, with trembling aspen, white birch and white cedar on the west.
Thick humus layer overlying bedrock.

Site 10

North-south aspect, open on the east, with white birch and white cedar on the west.
Thin humus layer overlying bedrock, with boulders in the north west corner of plot A, and much exposed bedrock on the north of plot B.

3.0 RESULTS AND DISCUSSION

The results of the nutrient analysis of the soil samples from the 10 sites are shown in Table IV, and an indication of the soil texture and thickness are found with the site descriptions in Table III. The mineral soil is a thin (5 to 15 cm), slightly acidic sand to sandy loam, covered by a thicker (10-15 cm) humus layer. The bedrock is close to the surface, and is exposed in some areas. The potassium levels are within the medium to medium-plus range of soil fertility ratings for turf grasses and pastures, while in the low range for berries, shrubs and tree nursery stock. (Ontario Soil Management Research Committee, University of Guelph, 1987). The magnesium concentrations are higher than the recommended requirement, while calcium and soil pH are within the range acceptable for growth. The concentrations of potassium and calcium are comparable to those previously reported for the soils in the transmission rights-of-way near Barrie (Brown 1988), while the magnesium levels are an order of magnitude higher. A high organic matter content was also recorded in the soils (47%±21, mean±SD, Table IV).

Table IV

Soil nutrient conditions of the proposed study sites

Site	Magnesium µg/mL	Potassium µg/mL	Calcium µg/g	pH	Organic matter %
1	529	64	1760	6.2	10
2	1125	39	2340	6.2	37
3	1238	97	3160	6.5	50
4	925	94	3420	5.6	18
5	1042	63	2890	6.5	67
6	1500	65	3000	5.7	72
7	2000	63	3160	6.8	33
8	812	75	3420	5.5	70
9	818	73	2910	5.3	45
10	1089	68	2970	5.8	65
mean	1108	70	2903	6.0	47
SD	389	16	480	0.5	21

The rights-of-way were heavily overgrown with woody vegetation, with a mean density of 1.163 stems m^{-2} recorded for the trees and tall shrubs in the macroquadrats studied. Balsam fir (*Abies balsamea*) was the predominant tree species, occurring in 19 of the macroquadrats at a density of 0.723 stems m^{-2} (Table V). White cedar (*Thuja occidentalis*) was found in all 20 macroquadrats, with a density of 0.279 stems m^{-2}. White birch (*Betula papyrifera*) was a minor component of the tree stratum in 7 quadrats (density of 0.021 stems m^{-2}). Nineteen other shrubs or trees were present, but occurred at very low densities and frequencies in the macroquadrats. (Table V).

Table V

The number of woody stems and their occurrences in the 5 x 10 m macroquadrats at the proposed study sites

Species[1]	Quadrat																				Density	Occurrence
	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B	stems·m^{-2}	
Abie Bal	33	50	0	8	32	19	19	73	26	54	9	14	23	28	39	62	39	87	68	40	0.723	19
Thuj occ	8	18	14	4	16	16	4	12	15	51	15	17	9	7	19	7	11	6	19	11	0.279	20
Dier loi	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.025	1
Betu pap	1	0	2	12	0	1	0	0	1	3	0	0	0	0	1	0	0	0	0	0	0.021	7
Corn Rug	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0.020	1
Popu bal	0	0	2	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.017	2
Pice mar	0	0	0	0	0	0	0	0	11	4	0	0	0	0	0	0	0	0	0	0	0.015	2
Popu tre	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5	2	4	0	0	0.012	4
Prun vir	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0.011	1
Sali sp.	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.008	1
Pice gla	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	0	0	0	1	0	0.007	3
Cory cor	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.005	1
Loni obl	2	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0.005	3
Shep can	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0.003	1
Corn sp.	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	2
Frax pen	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	2
Juni hor	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	1
Sorb ame	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	2
Aesc ped	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	1
Juni com	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0.001	1
Loni can	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0.001	1
Prun ser	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	1

1 Species abbreviation consists of the first 4 letters of the genus and first 3 letters of the species names (see Table II).

A total of 94 species were recorded in the 200 microquadrats used to estimate the ground cover (Table V). The majority of these (67) could be considered as occasional species, occurring in less than 5% of the samples. Twinflower (*Linnaea borealis*), starflower (*Trientalis borealis*) and flowering wintergreen (*Polygala paucifolia*) were the predominant plants in the understory, occurring in 116, 87 and 84 microquadrats respectively. The dominant trees, balsam fir and white cedar, were also frequently found in the microquadrats (17 and 33 respectively), and their branches overlapped several other microquadrats. Wild lily-of-the-valley (*Maianthemum canadense*), large-leaved aster (*Aster macrophyllus*), strawberry (*Fragaria virginiana*), bunchberry (*Cornus canadensis*), raspberry (*Rubus idaeus*), common daisy (*Chrysanthemum leucanthemum*) and wild basil (*Satureja vulgaris*) were the only other plants which occurred with a frequency greater than 10%.

The sample ordination of the microquadrats is shown in Figure 3. This plot indicates that the sites are fairly similar in composition, clustering below 100 on the first axis, and below 140 on the second. The exception to this are the quadrats from site 2, which were placed between 100 and 700 on the first axis. These quadrats were dominated by common daisy, field horsetail (*Equisetum arvense*), Canada goldenrod (*Solidago canadensis*) and Canada bluegrass (*Poa compressa*), and lacked most of the species characteristic of the other sites. Site 2 had gravely soil, with an unusually low concentration of potassium (2 standard deviations below the site means, Table IV). Similar potassium levels were observed in the soils which supported a class of vegetation dominated by common daisy and field horsetail on the transmission rights-of-way near Barrie (Brown 1988).

4.0 PROPOSAL FOR FUTURE EXPERIMENTATION

The experimental testing of cover crops will involve a comparison of the rate of invasion of tree species into plots seeded with the different crops and control plots. It is desirable to have the initial conditions similar at all locations to allow direct comparisons of the sites and simplify the interpretation of the results. The uniformity of the vegetation at 9 of these sites (Figure 3) is therefore extremely advantageous to the experimental design.

Extensive replication of sites is also important in this type of study. The rate of tree invasion will be dependent upon several factors: the type of vegetation cover, the density of the cover and the availability of tree propagules (fruits, seeds and root suckers). It is necessary to have the experimental block replicated at several sites to provide adequate estimates for the variability in crop establishment, tree invasion and to guard against damage to the site due to uncontrollable external forces (accidental herbicide applications, future real estate development, et cetera). It is proposed that the experiment incorporate all 10 sites of the English Harbour - Pendal Point right-of-way in a random block design, with the provision that site 2 may be dropped from the analysis if its control plot continues to differ from the other nine.

Within each site, 5 50 x 10 m plots will be created and randomly assigned to a treatment. All plots will be cleared of incompatible vegetation in accordance to Ontario Hydro's current management policies for this area (cut stump application of Weedone CB). The treatments will consist of: 1) soil scarification and seeding with a grass cover crop, 2) soil scarification, seeding with a grass cover crop and application of fertilizer, 3) soil scarification and seeding with a leguminous cover crop, 4) soil scarification and natural development of ground vegetation and 5) no soil scarification and natural development of ground vegetation.

Treatment 5 constitutes the current vegetational practices in right-of-way maintenance, thus represents the overall experimental control to which the other treatments will ultimately be compared. Good establishment of the cover crop is essential to the study, therefore scarification

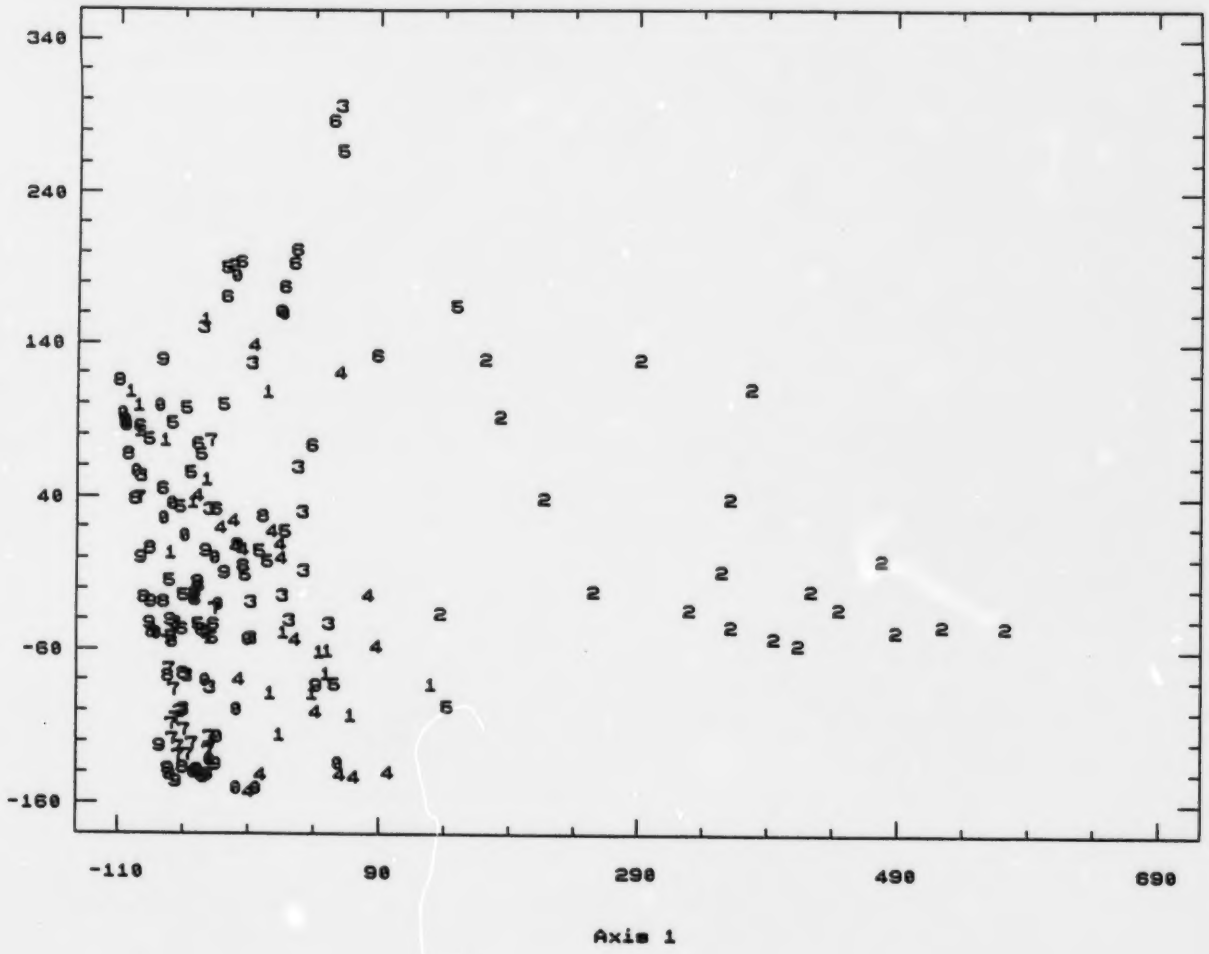

FIGURE 3

THE RECIPROCAL AVERAGING ORDINATION OF THE 200 MICROQUADRATS FROM THE 10 SAMPLING SITES ON THE EAGLE HARBOUR TO PENDAL POINT RIGHT - OF - WAY. THE NUMBERS INDICATE THE SITE FOR EACH MICROQUADRAT

of the soil is necessary to disrupt the existing vegetation cover and prepare a receptive seedbed for the crop. Treatment 4 is a control necessary to separate the effect of the cover crop from that of the scarification procedure. The testing of several cover crop candidates is better undertaken in a greenhouse or garden experiment, therefore this field experiment will be restricted to 2 types of crops, a grass (treatments 1 and 2) and a legume (treatment 3). Several researchers have indicated that the addition of fertilizers can enhance the interference effects of herbaceous vegetation on trees (Whitney et al. 1987, West 1987), thus treatment 2 will test this hypothesis for the grass cover crop, with treatment 1 acting as a control.

It may be necessary to re-seed the crops in areas of poor establishment during the second or third year. To maintain a valid comparison, periodic weeding of the control sites will also be required to prevent invasion by the experimental crops.

Evaluation of the experiment must be conducted over a period of several years. This must involve an estimate of tree invasion and an analysis of the ground covers in all plots. Additional manipulations to more fully investigate the interference effects may also be desirable in some plots.

An estimate of the tree invasion in all plots at all sites should be made during the establishment, maturation and senescent phases of the cover crop lifespan. This will involve sampling at the end of the year of planting, at yearly intervals for an additional 3 to 4 years, and subsequently at periodic intervals. This sampling scheme will indicate which stage of the vegetation's lifecycle is more susceptible to invasion, and provide an estimate of the useful longevity of the crops.

As mentioned above, the invasive forces active at each site and plot will differ, thus a high natural variance may be observed which will obscure the experimental trends. One method of overcoming this is to utilize a bioassay to compare the interference effects at some sites independent of the natural invasive forces. Two short term experiments are proposed for this assay. The interference effects of the different vegetation types on seed germination and establishment may be estimated by placing a known quantity of viable tree seeds in the plots and monitoring germination. An estimate of the interference effects on established trees can be assayed by transplanting bare root stock saplings into the plots and comparing subsequent growth. These experiments should be conducted 3 to 4 years after the establishment of the cover crop. This would ensure a good development of the cover crop prior to the experiment, and allow for some of the interactive effects between the crops and the soil (alterations in nutrients, moisture, temperature and allelopathic substances) to become well developed.

Analysis of the vegetation should be done on a yearly basis during the first 4 to 5 years, and periodically following this. This will provide an estimate for the rate of establishment of the cover crops and the changes in the natural control vegetation as a response to clearing operations. Monitoring of environmental conditions (soil nutrient levels, soil moisture, microclimate and presence of allelopathic compounds) at some sites will also be desirable to provide an indication of factors which may be important in the interference mechanism. An understanding of this process will be beneficial in selection of the appropriate cover crops for use in other locations.

Table VI presents a literature summary of the species implicated in interference reactions with trees. Many of these papers are reports of field observations or correlation studies, suggesting that the species may be useful inhibitors of tree growth without supplying experimental evidence to reinforce this. Suffling (1979) suggests that pseudo-stable communities are more likely to result from herbaceous cover rather than from the shrub communities proposed by Egler (1958). Although dense shrub thickets will form stable covers (Pound and Egler 1953, Niering et al. 1986), Suffling suggests that establishment of such dense growth via transplants or direct seeding

is unlikely, thus woody species will not be considered for this project.

A grass crop and a nitrogen fixing legume were chosen to provide contrasting growth forms and nutrient regimes in the study. It should be emphasized that the interference ability is a species specific process. Differences within growth form classes are as important as between classes (Bramble and Byrnes 1976, Suffling 1979) and it would therefore be expected that other grasses or legumes will respond in a different manner than the two selected for this study.

Suffling's (1979) analysis of Ontario Hydro's past usage of cover crops indicate that the best effects were achieved from smooth brome grass (*Bromus inermis*) and timothy (*Phleum pratense*). However, he also noted that these grasses had a tendency to invade off right-of-way areas, and will likely pose problems by invading the control plots. Therefore they will not be considered in this study. Orchard grass (*Dactylis glomerata*), red fescue (*Festuca rubra*) and tall fescue (*F. arundinacea*) are the other grasses most often implicated in interference studies (Table VI). In a field study (Buckley 1984), red fescue completely prevented the establishment of directly seeded birch (*Betula alba*) and sycamore (*Acer pseudoplantanus*), while in greenhouse experiments it also inhibited the establishment of sweetgum (*Liquidambar styraciflua*) from seeds (Walters and Gilmore 1976). Both tall fescue and orchard grass reduced the growth of 2-year old apple trees by 50% (Shribbs and Skroach 1986). Bramble and Byrnes (1976) have observed that patches of tall fescue were seldom invaded by trees in their Pennsylvania right-of-way study. Orchard grass has been shown to reduce the growth of ponderosa pine (*Pinus ponderosa*) seedlings by 17% relative to the natural vegetation, and 25% relative to a bare ground control (Elliott and White 1987). Orchard grass seeded 5 months following transplanting of 1 year old Douglas fir (*Pseudotsuga menziesii*) was able to reduce the growth of the fir by a small but significant amount (Eissenstat and Michell 1983). Allelopathic effects have been observed for all three grasses (Walters and Gilmore 1976, Arron 1986).

Red fescue is a drought tolerant grass well adapted for sandy or gravely soils. The creeping variety will form a dense, uniform turf, and has been extensively used for erosion control, lawn and pastures. Tall fescue is a coarse bunchgrass used in rough turf and meadows. It forms dense clumps, does not creep, and grows well in moister areas. Orchard grass is also widely used in meadows and pastureland. Although it is included in Hydro's northern right-of-way grass mixture, it prefers fertile well-drained soils and less severe winter conditions. (Anon. 1983). From the above habitat descriptions, creeping red fescue would be the most probable of the grasses to establish well in the test area.

Legumes have been less well studied as a cover crop, their role often delegated to that of a nitrogen fixing companion species in a grass mixture. Mixed results have been obtained with white clover (*Trifolium repens*). This species was effective in inhibiting birch establishment from seeds (Buckley 1984). However, the same study indicated that although it inhibited the establishment of sycamore seeds, it stimulated growth of those seedlings which were able to establish. White sweet clover (*Melilotus alba*) was not as effective as orchard grass, but more effective than the natural vegetation in inhibiting the growth of ponderosa pine seedlings (Elliott and White 1987). Crown vetch (*Coronilla varia*) has been shown to be negatively associated with tree cover along highway rights-of-way in Pennsylvania and Maryland (Sharp et al. 1980). Suffling (1979) also indicated that crown vetch was the most promising of the three legumes included in his evaluation of Ontario Hydro's cover crops. Crown vetch is long lived, drought and salt tolerant, and will grow in shallow sandy soils (Anon. 1983). However, it is slow to establish, thus a nurse crop is recommended. This appears to be the most promising legume, and is recommended for this study. Perennial ryegrass (*Lolium muliflorum*) should be used as a nurse crop for both the crown vetch and fescue. It is quick to establish, but very susceptible to winter kill (Anon. 1983). Therefore it should not influence the study over the long term, but may

Table VI

The species implicated in other studies to be
either stimulatory, inhibitory or neutral in relation to
their interference effects on the establishment or growth of trees

Good Competitors

Cover crop	Target Species	Reference
bamboo, dwarf	cottonwood	Shoup & Whitcomb 1981
bent grass, common	ash	Buckley et al. 1981
	Norway maple	Buckley et al. 1981
Bermuda grass	dwarf holly	Whitcomb 1981
	chinese juniper	Whitcomb 1981
	Japanese black pine	Whitcomb 1981
birdsfoot trefoil	hybrid poplar	McLaughlin et al. 1985
blueberry, low		Pound & Egler 1953[a]
		Bramble & Byrnes 1976[a]
blueberry, dryland		Niering & Goodwin 1974[a]
blue grass, Kentucky	ash	Buckley et al. 1981
	Norway maple	Buckley et al. 1981
	apple	Shribbs & Skroch 1986
brome grass	trembling aspen	Bailey & Gupta 1973
	white ash	Suffling 1979
	sugar maple	Suffling 1979
burnet, small	ponderosa pine	Elliott & White 1987
Calamagrostis rubescens	ponderosa pine	Petersen 1988
ceanothus,snowbush	Douglas fir	Petersen & Newton 1982*
clover, white	birch	Buckley 1984
	Frasier fir	Warren et al. 1987
clover, red	Douglas fir	Eissenstat & Mitchell 1983
clover, white sweet	ponderosa pine	Elliott & White 1987
clubmoss	black cherry	Horsley 1977b[a]
fescue, Arizona	ponderosa pine	Larson & Schubert 1969*
fescue, red	birch	Buckley 1984
	sweetgum	Walters & Gilmore 1976
fescue, tall	black walnut	Todhunter & Beineke 1979*
	apple	Shribbs & Skroch 1986
		Bramble & Byrnes 1976[a]
goldenrod, grassleaved		Bramble & Byrnes 1976[a]
goldenrod,rough		Bramble & Byrnes 1976[a]
greenbrier		Niering & Goodwin 1974[a]
greenleaf manzanita	ponderosa pine	Shainsky & Radosevich 1986
	ponderosa pine	Rejmanek & Messina 1988
	Douglas fir	Rejmanek & Messina 1988

Table VI (cont'd)

The species implicated in other studies to be
either stimulatory, inhibitory or neutral in relation to
their interference effects on the establishment or growth of trees

Good Competitors (cont'd)

Cover crop	Target Species	Reference
Hayscented fern	black cherry	Horsley 1977b[a],1981
	sugar maple	Horsley 1977b[a]
	red maple	Horsley 1977b[a]
		Pound & Egler 1953[a]
huckleberry, black		Pound & Egler 1953[a]
		Niering & Goodwin 1974[a]
Ivy, English	cottonwood	Shoup & Whitcomb 1981
	silver maple	Shoup & Whitcomb 1981
liriope	cottonwood	Shoup & Whitcomb 1981
	silver maple	Shoup & Whitcomb 1981
little bluestem		Niering & Goodwin 1974[a]
loosestrife, prairie		Bramble & Byrnes 1976[a]
Mountain maple	balsam fir	Baskerville 1961*
	white spruce	Baskerville 1961*
nannyberry		Niering et al. 1986[a]
New York fern	black cherry	Horsley 1977b[a],1981[a]
	red maple	Horsley 1977b[a]
	sugar maple	Horsley 1977b[a]
		Pound & Egler 1953[a]
oak, bear		Bramble & Byrnes 1976[a]
oatgrass, tall	Ponderosa pine	Baron 1962*
short husk grass	black cherry	Horsley 1977b[a]
		Horsley 1977b[a]
orchard grass	ponderosa pine	Baron 1962*
	Douglas fir	Eissenstat & Mitchell 1983
	Frasier fir	Warren et al. 1987
	ponderosa pine	Elliott & White 1987
	apple	Shribbs & Skroch 1986
	apple	Rogers et al.1948
	apple	Shribbs et al. 1986
perennial ryegrass	ponderosa pine	Baron 1962*
	birch	Buckley 1984
	apple	Bould & Jarrett 1962
plantain	birch	Buckley 1984
ragweed	apple	Shribbs & Skroch 1986
red sorrel	apple	Shribbs & Skroch 1986
sainfoil	sugar maple	Suffling 1979
sheep laurel		Pound & Egler 1953[a]
sweet fern		Pound & Egler 1953[a]
timothy	ponderosa pine	Baron 1962*
	ash	Buckley et al. 1981
	Norway maple	Buckley et al. 1981

Table VI (cont'd)

The species implicated in other studies to be
either stimulatory, inhibitory or neutral in relation to
their interference effects on the establishment or growth of trees

Good Competitors (cont'd)

Cover crop	Target Species	Reference
	Douglas fir	Eissenstat & Mitchell 1983
	white birch	Suffling 1979
	apple	Bould & Jarrett 1962
vetch, crown		Sharp et. al 1980[a]
wheatgrass, crested	ponderosa pine	Elliott & White 1987
Yarrow	birch	Buckley 1984

Poor Competitors

Cover crop	Target Species	Reference
bamboo, dwarf	silver maple	Shoup & Whitcomb 1981
bluegrass, big	ponderosa pine	Baron 1962*
bluegrass, Canada		Suffling 1979
blueberry, low		Bramble & Byrnes 1976[a]
blackberry	apple	Shribbs & Skroch 1986
		Bramble & Byrnes 1976[a]
bracken fern		Bramble & Byrnes 1976[a]
clover, white	sycamore[c]	Buckley 1984
club moss	sugar maple	Horsley 1977b[a]
fescue, hard	ponderosa pine	Baron 1962*
hayscented fern		Bramble & Byrnes 1976[a]
huckleberry, black		Bramble & Byrnes 1976[a]
loosestrife, prairie		Bramble & Byrnes 1976[a]
nimbleweed	apple	Shribbs & Skroch 1986
oak, bear		Bramble & Byrnes 1976[a]
Pennsylvania sedge		Bramble & Byrnes 1976[a]
plantain	sycamore[c]	Buckley 1984
pubescent wheatgrass	ponderosa pine	Baron 1962*
raspberry	balsam fir[b]	Baskerville 1961*
	white spruce[b]	Baskerville 1961*
red sorrel	apple	Shribbs & Skroch 1986
red top	ponderosa pine	Baron 1962*
sweet fern		Bramble & Byrnes 1976[a]
wheat	apple	Shribbs & Skroch 1986

Table VI (cont'd)

The species implicated in other studies to be
either stimulatory, inhibitory or neutral in relation to
their interference effects on the establishment or growth of trees

Neutral Competitors

Cover crop	Target Species	Reference
aster, flattop	black cherry	Horsley 1981[d]
bracken fern	black cherry	Horsley 1981[d]
blue gramma	ponderosa pine	Elliott & White 1987
clover, white	apple	Bould & Jarrett 1962
goldenrod, rough	black cherry	Horsley 1981[d]
Korean lespedeza	apple	Shribbs & Skroch 1986
oat grass	black cherry	Horsley 1981
short husk grass	black cherry	Horsley 1981
squirrel tail	ponderosa pine	Elliott & White 1987

Comments

a field observations only, no proper experimental design
b raspberry invaded clearing following planting of tree
c cover inhibited germination but stimulated growth
d allelopathic effect of plant extracts on seed germination/growth for these species has been demonstrated by Horsley 1977a
* information taken from an abstract of the paper by Stewart et al. 1984

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provide a valuable cover until the test plants become established.

The study discussed above should provide an estimate of the effectiveness of the grass and legume crop used relative to that of the natural vegetation cover. It is important to emphasize that the results will have a large degree of site specificity, and that some crops will be more effective, while others will be less effective at this location than the two tested.

Ontario Hydro's recent adoption of a policy to restrict herbicide usage strongly emphasizes the immediate need to increase our research efforts on alternative control methodologies, and this project represents an important step in that direction.

5.0 CONCLUSIONS

1. Ten locations on the Pendal Point to Hopkins Bay distribution line have been selected for an experimental evaluation of the ability of red fescue (*Festuca rubra*) and crown vetch *Coronilla varia*) to interfere with the establishment of incompatible vegetation on the rights-of-way.

2. The major incompatible species in this area consist of balsam fir (*Abies balsamea*, density of 0.723 stems m^{-2}), white cedar (*Thuja occidentalis*, density of 0.279 stems m^{-2}) and white birch (*Betula papyrifera*, density of 0.021 stems m^{-2}).

3. The ground vegetation at 9 sites was dominated by twinflower (*Linnaea borealis*), starflower (*Trientalis borealis*) and flowering wintergreen (*Polygala paucifolia*). The other site was dominated by common daisy (*Chrysanthemum leucanthemum*), field horsetail (*Equisetum arvense*), Canada goldenrod (*Solidago canadensis*) and Canada bluegrass (*Poa compressa*).

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REFERENCES

Anonymous 1983. A guide to seeding rights-of-way cover crops. Ontario Hydro HG&1. Department of Transmission Environment.

Arron, G.P. 1986. Effects of aqueous extracts of cover crops on seed germination: influence of cover crop age and total phenolics content. Ontario Hydro Research Division Report C86-184-K

Bailey, A.W. and R.K. Gupta. 1973. Grass-woody plant relationships. Canadian Journal of Plant Science 53,671-676.

Bould, C. and R.M. Jarrett. 1962. The effect of cover crops and NPK fertilizers on growth, crop yield and leaf nutrient status of young dessert apple trees. Journal of Horticultural Science 37,58-82.

Bramble, W.C. and W.R. Byrnes. 1976. Development of a stable, low plant cover on a utility right-of-way. Proceedings of the first international symposium on environmental concerns in right-of-way management. Mississippi State University Press. p 168-176.

Brown, D. 1988. The relationships between vegetation, soil texture, nutrient status and herbicide treatments on transmission rights-of-way in the vicinity of Essa TS, Georgian Bay Region. Ontario Hydro Research Division Report 88-211-K.

Buckley, G.P. 1984. The uses of herbaceous companion species in the establishment of woody species from seed. Journal of Environmental Management 18, 309-322.

Buckley, G.P., K.G. Chilton and V.G. Devonald. 1981. The influence of sward control on the establishment and early growth of ash (Fraxinus excelsior L.) and Norway maple (Acer platanoides L.) Journal of Environmental Management 13, 223-240.

Egler, F.E. 1958. Science, industry, and the abuse of rights of way. Science 127,573-580.

Eissenstat, D.M. and J.E. Mitchell. 1983. Effects of seeding grass and clover on growth and water potential of Douglas-fir seedlings. Forest Science 29, 166-179.

Elliott, K. and A.S. White. 1987. Competitive effects of various grasses and forbs on ponderosa pine seedlings. Forest Science 33, 356-366.

Fernald, M.L. 1950. Gray's manual of Botany. Eighth edition. D. van Nostrand and Co., New York.

Fisher, R. F. 1980. Allelopathy: a potential cause of regeneration failure. Journal of Forestry 78,346-350

Hill, M.O., and H.G. Gauch. 1980. Detrended correspondence analysis: an improved ordination technique. Vegetatio 42,47-58.

Horsley, S.B. 1981. Control of herbaceous weeds in Allegheny hardwood forests with herbicides. Weed Science 29, 655-662.

Horsley, S.B. 1977a. Allelopathic inhibition of black cherry by fern, grass, goldenrod, and aster. Canadian Journal of Forest Research 7, 205-216.

Horsley, S.B. 1977b. Allelopathic inhibition of black cherry. II. Inhibition by woodland grass, ferns, and club moss. Canadian Journal of Forest Research 7, 515-519.

Hosie, R.C. 1979. Native trees of Canada. Fitzhenry and Whiteside Ltd. Don Mills.

Johnston, P.A. 1985. Long-term right-of-way effectiveness. ESEERCO Research Report EP83-15.

Jotcham, J.R. 1985. Environmental properties of triclopyr. M.Sc. thesis, University of Guelph.

McLaughlin, R.A.,P.E. Pope and E.A. Hansen. 1985. Nitrogen fertilization and ground cover in a hybrid poplar plantation: effects on nitrate leaching. Journal of Environmental Quality 14, 241-245.

Niering, W.A., G.D. Dreyer, F.E. Egler and J.P. Anderson Jr. 1986. Stability of a *Viburnum lentago* shrub community after 30 years. Bulletin of the Torrey Botanical Club 113, 23-27.

Niering, W.A. and R.H. Goodwin. 1974. Creation of relatively stable shrublands with herbicides: arresting "succession" on rights-of-way and pastureland. Ecology 55,784-795.

Petersen, T.D. 1988. Effects of interference from *Calamagrostis rubescens* on size distribution in stands of *Pinus ponderosa*. Journal of Applied Ecology 25, 265-272.

Pound, C.E. and F.E. Egler. 1953. Brush control in southeastern New York: fifteen years of stable tree-less communities. Ecology 34, 63-73.

Rejmanek, M. and J. Messina. 1988. Growth responses of conifer seedlings to shrub competition: a comparison of neighborhood predictors. Bulletin of the Ecological Society of America 69:273.

Rogers, W.S., Th. Raptopoulos and D.W.P. Greenham. 1948. Cover crops for fruit plantations. IV. Long-term leys and permanent swards. Journal of Horticultural Science 24, 228-270.

Shainsky, L.J. and S.R. Radosevich. 1986. Growth and water potential of Pinus ponderosa seedlings in competitive regimes with Arctostaphylos patula seedlings. Journal of Applied Ecology 23, 957-966.

Sharp, W.C. , R.S. Ross, .W. Testerman and R. Williamson. 1980. Ability of crownvetch to suppress woody plant invasion. Journal of Soil and Water Conservation May-June 1980,142-144

Shoup, S. and C.E. Whitcomb 1981. Interactions between trees and ground covers. Journal of Arboriculture 7, 186-187.

Shribbs, J. and W.A. Skroch. 1986. Influence of 12 ground cover systems on young 'smoothee golden delicious' apple trees. I. Growth. Journal of the American Society of Horticultural Science 111,525-528.

Soper, J.H. and M.L. Heimburger. 1982. Shrubs of Ontario. Royal Ontario Museum, Toronto.

Stewart, R.E., L.L. Gross and B.H. Honkala. 1984. Effects of competing vegetation on forest trees: a bibliography with abstracts. United States Department of Agriculture, Forest Service. General Technical Report WO-43

Suffling, R. 1979. Environmental aspects of cover crops on Ontario Hydro rights-of-way. Waterloo Research Institute Project 707-11.

Tilman, D. 1985. The resource-ratio hypothesis of plant succession. The American Naturalist 125, 827-852.

Walters, D.T. and A.R. Gilmore. 1976. Allelopathic effects of fescue on the growth of sweetgum. Journal of Chemical Ecology 2, 469-479.

Warren, S.L., W.A. Skroch and L.E. Hinesley. 1987. Effect of root competition and nitrogen on growth and mineral content of Abies fraseri. Canadian Journal of Forest Research 17, 1092-1099.

Whitcomb, C.E. 1981. Response of woody landscape plants to Bermudagrass competition and fertility. Journal of Arboriculture 7,191-194.